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REPORT

Damage to a residence in Anna, Ohio, as a result of the March 1937 earthquakes (photo courtesy of E. A. Bradley, Xavier University).

ADDITIONAL READING

Bradley, E. A., and Bennett, T. J., 1965, Earthquake history of Ohio: Seismol. Soc. of America Bull., v. 55, p. 745-752.

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Modified Mercalli intensity scale

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck.

IV. During the day, felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown [illegible] into air.

ODNR
OHIO DEPARTMENT OF NATURAL RESOURCES

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INTRODUCTION

Earthquakes can be one of the most terrifying of natural phenomena. Catastrophic loss of life and mass destruction of property are typical of major earthquakes that strike in populated regions of the world. Witnesses to severe earthquakes describe loud rumbling noises, crashing of furniture and objects across the room, collapse of masonry buildings and other structures, and prominent cracking and offset of the ground surface. Commonly contributing further to the chaos are fires and disruption of communications caused by the snapping of water, gas, electric, and telephone lines.

Ohio has a comparatively low potential for severe earthquake damage, although more than 90 probable earthquakes with origins in the state and of an intensity great enough to be felt by people in local or wide areas have been recorded since 1776. In addition, several earthquakes with origins outside of Ohio have been felt within the state. Most of these shocks have caused little or no damage, although a few have caused moderate damage in localized areas.

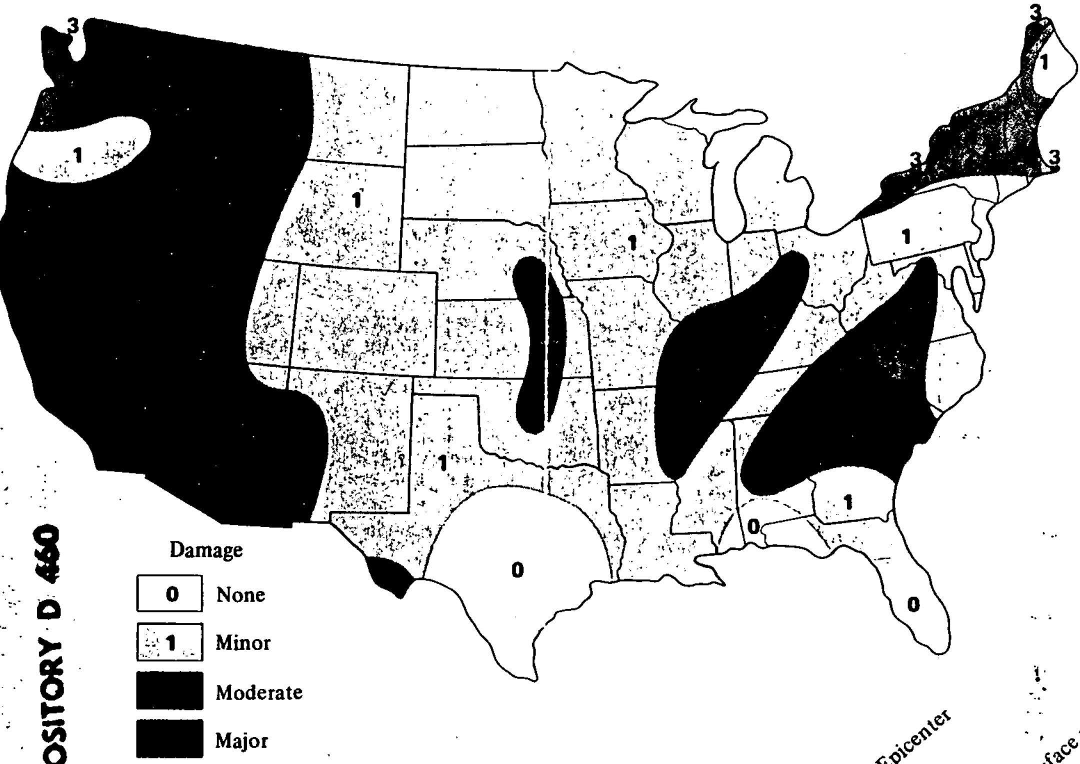
In regions prone to severe earthquakes the designing of buildings and other structures to withstand the stresses of a major shock can considerably reduce damage and loss of life. In addition, proper zoning regulations based upon detailed geologic information can greatly reduce the effects of potential earthquake hazards on manmade structures. Objectives of seismic (earthquake) research include prediction of earthquakes by continuous monitoring of strain in rocks of major populated seismic areas and artificial release of stress before it has accumulated to levels sufficient to generate a major earthquake.

The accompanying seismic-risk map of the United States delineates the degree of risk of earthquake damage. In zone 0 no damage can be anticipated. In zone 1, which includes most of Ohio, only minor damage from earthquakes can be expected. Areas in zone 2 may expect moderate damage, such as toppling of chimneys and cracking of masonry structures and windows. West-central and southwestern Ohio and a small area in northeastern Ohio along Lake Erie are in this zone. Areas in zone 3 may experience major destructive earthquakes. No part of Ohio is located in this zone. This seismic-risk map is based upon a collection of historical earthquake data accumulated over many years and indicates that, while it is not impossible, it is very improbable that Ohio would experience a severe earthquake.

ORIGIN OF EARTHQUAKES

Most earthquakes result when great pressures exerted upon the brittle rocks of the earth's crust initiate movements along fractures, called faults, in the rocks. An earthquake occurs when stresses become great enough to overcome the frictional resistance of the rock units on either side of a fault. The resultant movement along the fault may be rapid, releasing tremendous amounts of energy which have accumulated over a long period of time. Shock waves, much like ripples created when a pebble is thrown into a quiet pool, radiate in all directions from the point where the movement along the fault occurred. Although movements along faults are by far the most common cause, earthquakes also can be generated by other geologic activities, such as volcanic eruption, cavern collapse, and major landslides. The recent theory of plate tectonics (continental drift) suggests that much of the major worldwide earthquake activity is a product of stresses associated with the slow movement of several slablike plates of the earth's rigid outer shell.

General seismic-risk map for conterminous United States.

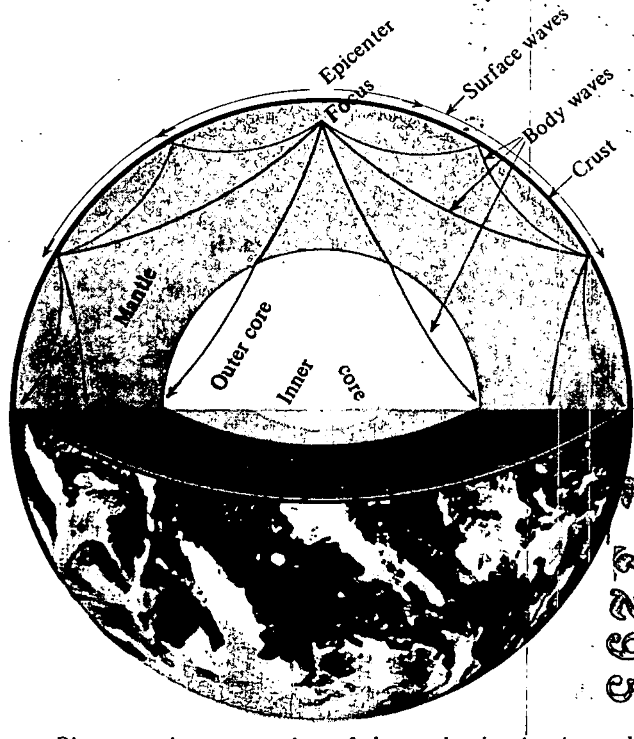


The majority of earthquakes occur at shallow (0-40 miles, or 0-64 kilometers) or intermediate (40-180 miles, or 64-288 kilometers) depths. A few originate at depths up to 440 miles (704 kilometers). The point within the earth at which an earthquake originates is called its focus. The point on the earth's surface directly above the focus is termed the epicenter. Damage to manmade structures is generally greatest at the epicenter.

EARTHQUAKE WAVES

An earthquake generates detectable seismic waves that radiate outward from the focus as manifestations of the energy released by the quake. Two principal types of seismic waves are recognized: (1) body waves, which move through the interior of the earth, and (2) surface waves, which travel along the earth's surface.

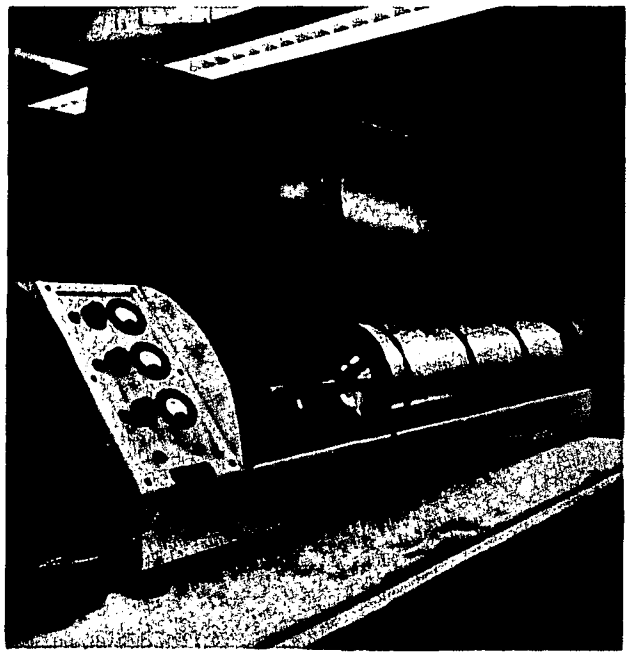
Seismic waves generated by earthquakes are useful to earth scientists in the measurement and study of earthquakes. Moreover, seismic waves provide essentially the only available information on the structure and composition of the earth's interior. Owing to the variable behavior of earthquake waves as they pass through matter of different density and state (liquid or solid), the layered structure of the earth's interior has been determined, as illustrated on the accompanying diagram.



Diagrammatic cross section of the earth, showing internal layering, hypothetical earthquake focus and epicenter, and paths of body and surface waves.

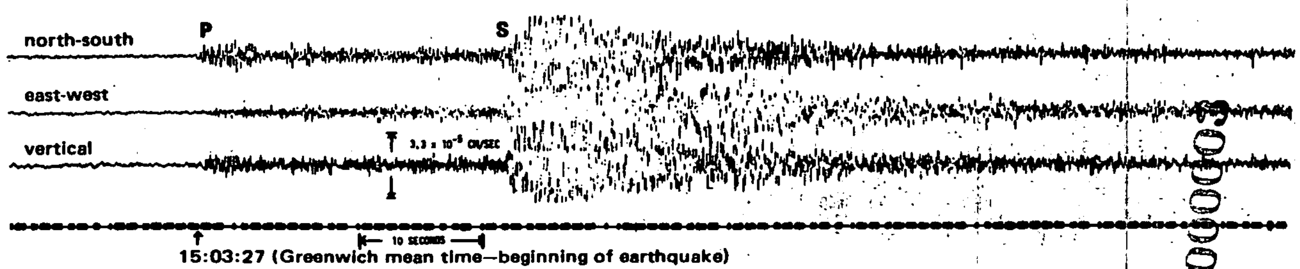
MEASUREMENT OF EARTHQUAKES

Earthquakes are detected and measured by means of instruments known as seismographs, which operate on the following principle. A heavy weight suspended by a spring from a base mounted firmly in bedrock will tend to remain at rest because of inertia; however, the base of the seismograph moves in conjunction with the earth during an earthquake. This relative motion between the suspended weight and the base generates a signal, which commonly is recorded photographically or electronically on paper attached to a rotating drum. This record of an earthquake is known as a seismogram. Many modern seismological stations record seismic data on magnetic tape to permit rapid computer processing and analysis of information. These data, gathered from a worldwide network of seismograph stations, are compiled and used to calculate the epicenter, magnitude, and time of origin of an earthquake. There are three seismograph stations in Ohio: at Xavier University in Cincinnati, at John Carroll University in Cleveland, and at Bowling Green State University in Bowling Green.

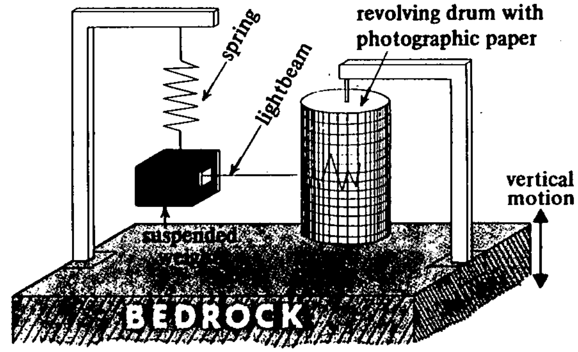


Triple-drum seismic recorder (photo courtesy of John Carroll University, Seismological Observatory).

Earthquakes are measured by two commonly used scales. The Richter scale is an instrumental scale that measures, by means of a seismograph, the strength of an earthquake from the amplitude of seismic waves generated by the shock. The measurement is expressed as a number, termed the magnitude, which can be related to the energy released by an earthquake. Magnitudes have no lower or upper limits, although the largest recorded was 8.9 and the smallest, which is dependent upon instrument sensitivity and other factors, was about minus 3. The severe 1964 Alaskan earthquake had a Richter magnitude of 8.4. The Richter scale is logarithmic; therefore, each whole-number increase on the scale represents an increase of ground motion or seismograph amplitudes of about 10 times. Magnitudes of about 2 are the smallest quakes felt by people; major quakes are usually those with magnitudes of 7 or greater.



Three-component seismogram of the July 26, 1968, Anna, Ohio, earthquake (magnitude 3.0, Intensity III) as recorded by seismometers in the bottom of a 1200-foot borehole at the University of Michigan; P indicates arrival of the compression body wave; S indicates the arrival of the shear body wave (after Willis and Wilson, 1970).



Simplified diagrammatic sketch of a vertical-component seismograph. The suspended weight remains at rest because of its inertia; the base and drum move in response to seismic waves.

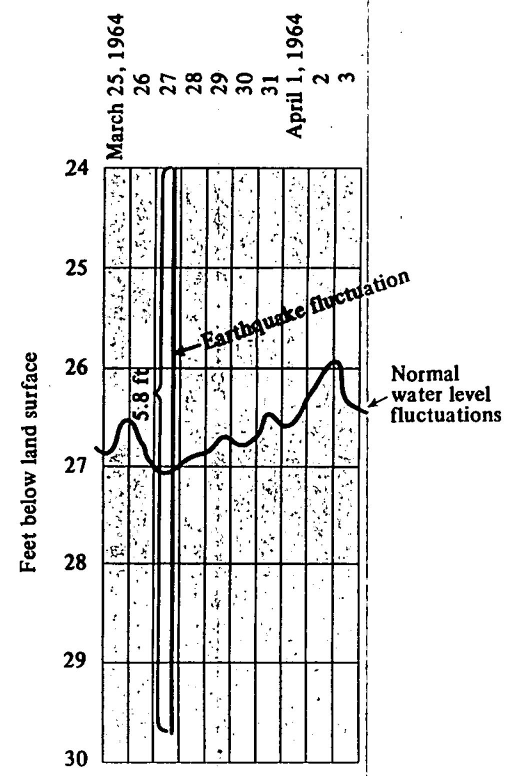
Intensity, a measure of the severity of ground shaking at a particular point, is indicated by the modified Mercalli scale. There are twelve Mercalli intensities, represented by roman numerals. These intensities are subjective because they are based upon damages incurred by buildings and effects felt by people in localized areas. Intensity is usually greatest at the epicenter of an earthquake and decreases with distance from the epicenter. The highest intensity reported for any earthquake in Ohio is VIII. Each earthquake has only one magnitude, although it may have several intensities.

Approximate relationships of earthquake phenomena[1, 2]

Richter magnitude	Expected annual incidence (worldwide)	Felt area (sq mi)	Maximum modified Mercalli intensity
3.0-3.9	49,000	750	II-III
4.0-4.9	6,200	3,000	IV-V
5.0-5.9	800	15,000	VI-VII
6.0-6.9	120	50,000	VII-VIII
7.0-7.9	18	200,000	IX-X
8.0-8.9	1	800,000	XI-XII

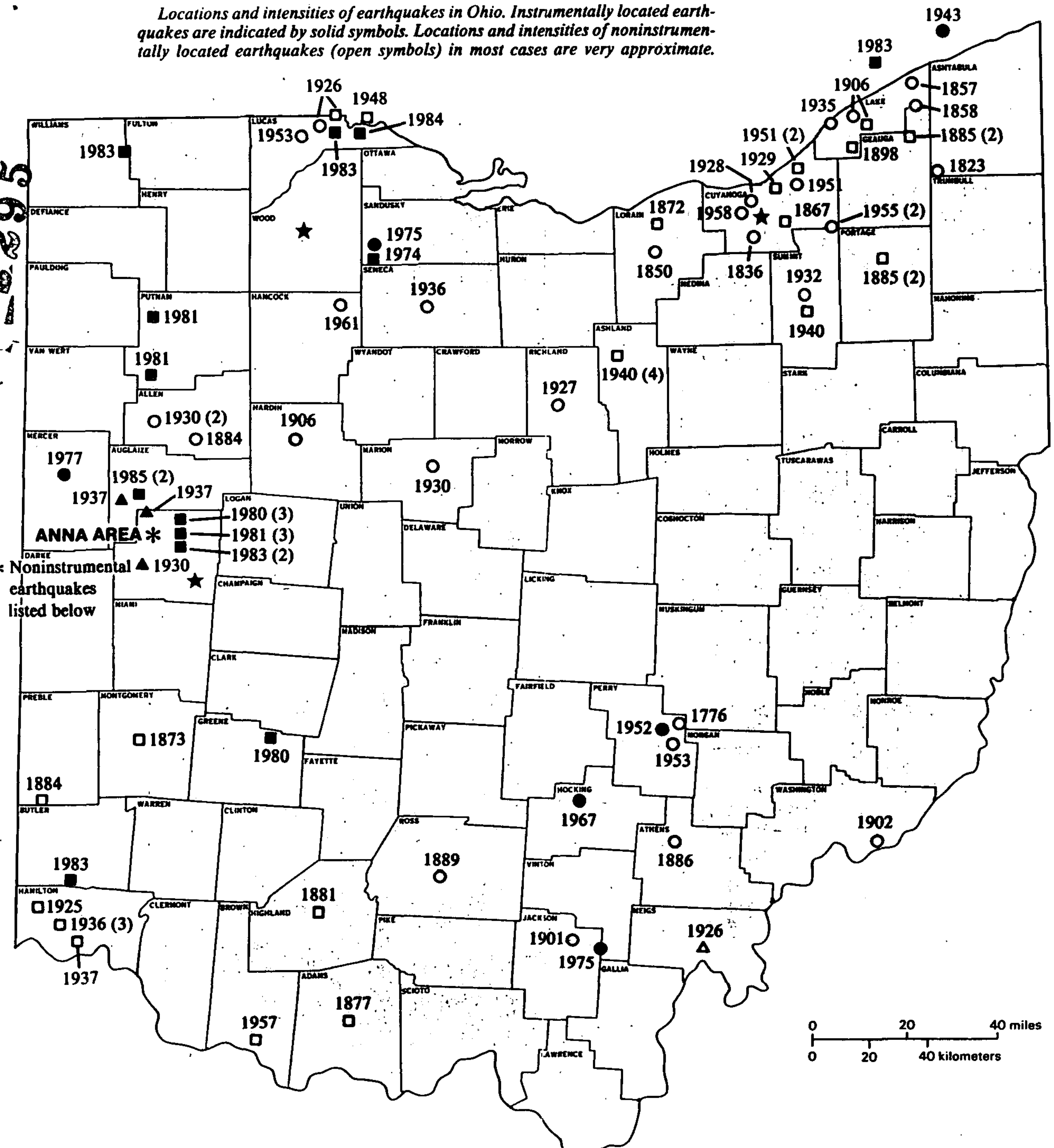
[1]Modified from Environmental Science Service Administration (1969).
[2]Depending upon local geology, relationships may vary with individual earthquakes.

Additional evidence of some earthquakes is preserved by water-level recorders in observation wells, 110 of which are maintained in Ohio by the Division of Geological Survey. The passing of seismic waves, sometimes from distant quakes, through rock strata causes alternate compression and expansion of the rocks. Water levels in wells may rise and fall markedly in response to these seismic waves. A Division of Geological Survey well in Van Wert County recorded a change in water level of 5.8 feet when seismic waves from the 1964 Alaskan earthquake passed through the state.



Variation of water level in an observation well in Van Wert County, Ohio, in response to the March 27, 1964, Alaskan earthquake.

Locations and intensities of earthquakes in Ohio. Instrumentally located earthquakes are indicated by solid symbols. Locations and intensities of noninstrumentally located earthquakes (open symbols) in most cases are very approximate.



* Noninstrumental earthquakes in the Anna area

△ 1875	○ 1892	○ 1929	□ 1931 (3)	○ 1939
□ 1876	○ 1896	△ 1930	□ 1933	□ 1939 (3)
○ 1882	□ 1925	□ 1930 (2)	○ 1933	□ 1944
□ 1884	○ 1925	□ 1930 (2)	○ 1937	○ 1956
□ 1889	□ 1928	△ 1931	□ 1937 (4)	□ 1968

Figures in parentheses indicate number of earthquakes.

Modified Mercalli intensity

■ I - III
● IV - VI
▲ VII - VIII
★ Seismograph station(s)

EARTHQUAKES IN OHIO

Compared to seismically active areas of the United States, such as parts of California or Alaska, Ohio has relatively few earthquakes. The most frequent and damaging earthquakes in the state have originated in the vicinity of the western Ohio town of Anna, in Shelby County. During the last 100 years the Anna area has experienced more than 30 earthquakes; the decade of the 1930's was the seismically most active period. During this time 23 earthquakes were recorded, including the most severe shock ever reported from Ohio. This earthquake, which occurred on March 9, 1937, had a reported intensity of VIII on the modified Mercalli scale and was felt over an area of 150,000 square miles. A shock of intensity VII preceded the March 9 quake by 7 days. Considerable damage—breaking of dishes and windows, cracking of plaster on ceilings and walls, and extensive cracking of masonry in several large buildings, including the school, the firehouse, and two churches—was done to buildings in Anna and nearby communities by these quakes. Nearly every chimney in the community was damaged and monuments in the cemeteries were rotated on their bases. Considerable alarm was expressed by Anna's residents, and rumors of impending destruction and disaster spread through the community. However, when this fear failed to materialize, Anna's populace soon returned to normal. Since the considerable activity of the 1930's only 3 minor earthquakes have been centered in the Anna area.

Other areas of localized earthquake activity include northeastern Ohio, where 24 earthquakes have been reported since 1823. Most of these have been of minor intensity, causing little or no damage. Ten earthquakes have been reported from southeastern Ohio since 1776, all of minor intensity with little damage recorded. Other areas of minor localized activity include the Cincinnati area and the vicinity of Toledo.

CAUSE OF OHIO'S EARTHQUAKES

The precise cause or causes of earthquakes in Ohio are poorly understood. Data from recent tremors indicate focal depths of 12 to 18 miles (20 to 30 kilometers) or less. These shallow-focus earthquakes suggest minor crustal adjustments like those which occur continuously in many parts of the world. The specific nature of these adjustments in Ohio is unknown.

One factor partially responsible for the lack of precise data on the location of active faults or other bedrock structures responsible for Ohio's earthquakes is the relative infrequency of significant seismic activity within the state. Collection of definitive data on these bedrock structures is partially dependent upon the occurrence of earthquakes that are strong enough to be recorded simultaneously by a number of standardized seismograph stations. However, no earthquakes of sufficient magnitude have occurred within the state since an adequate distribution of standardized seismographs became available in the 1960's. Perhaps future research will provide data from which more precise conclusions can be drawn as to the cause of Ohio's earthquakes.